5. EXHAUST SYSTEMS

Exhaust sparks usually carbon chunks or flakes, have long been the single greatest cause of railroad right-of-way (R/W) fires, although in some areas this may not be true.

Photograph 5-1.
Exhaust Stack with Carbon Build-Up

5.1 Normally Aspirated Diesel Engines

On this type of diesel engine the intake air is supercharged by means of a gear-driven blower. The most common of these is the Roots Blower. Crankcase fumes are withdrawn (“aspirated”) by a tube connecting the crankcase through an oil separator with the intake side of the blower where a slight vacuum exists. Thus the crankcase fumes pass through the cylinders and if any oil is present in them it is burned along with the fuel oil. The exhaust carbon created in this configuration is generally hard, nonporous and very hot. It cools rapidly in open air but can easily start fires in dry vegetation or other flammable material if it is large enough to maintain a temperature at or above their ignition level for any significant time. Therefore it is important to either trap the particles or break them up into pieces too small to cause a fire problem. Two basic methods have been employed for doing this: screens and spark arresters.

Photograph 5-2.
Roots Blower - EMD

Screens are the oldest and simplest method of preventing the escape of carbon particles. Screens are usually attached to the top of the exhaust stock. They are not, however, sufficiently effective and can cause other problems. If the holes are small enough to stop all dangerous particles they cause excessive backpressure. Screens also tend to clog up and burn out, thus requiring frequent cleaning and replacement. They are no longer used on road engines; their use is now confined to smaller and older yard and switch engines.

Photograph 5-3.
Exhaust Stack with Illegal Screen
(Requires an Approved Spark Arrester)

Photograph 5-4.
Illegal Screen (Requires an Approved Spark Arrester)

Photograph 5-5.
Screen Stack (Illegal - Requires an Approved Spark Arrester)

Modern locomotive spark arresters are of the vortex type wherein the exhaust gasses are directed tangentially into a cylindrical chamber at various points along the chamber but expelled at only one point, producing a spiral motion of the gasses in the chamber. There are two variations of this system: the attrition arrester and the retention arrester.

The retention spark arrester depends upon centrifugal force to throw the carbon particles, which are much heavier than the gasses carrying them, against the outer walls of the chamber. From here they are channeled to externally mounted traps which can be emptied by removing a cap on the bottom. It has been found from experience that, unless the engine is in perfect condition, these traps tend to fill up quickly. This destroys the arresting capability of the system and sparks start going out of the stock. Therefore, it is recommended that the traps be emptied not less than every seven days. Some companies do this every five days. In California both attrition and retention spark arresters rated and approved by the U.S. Forest Service are legal unless it can be proved that particles larger than 0.0232 inch in diameter will escape the exhaust system.

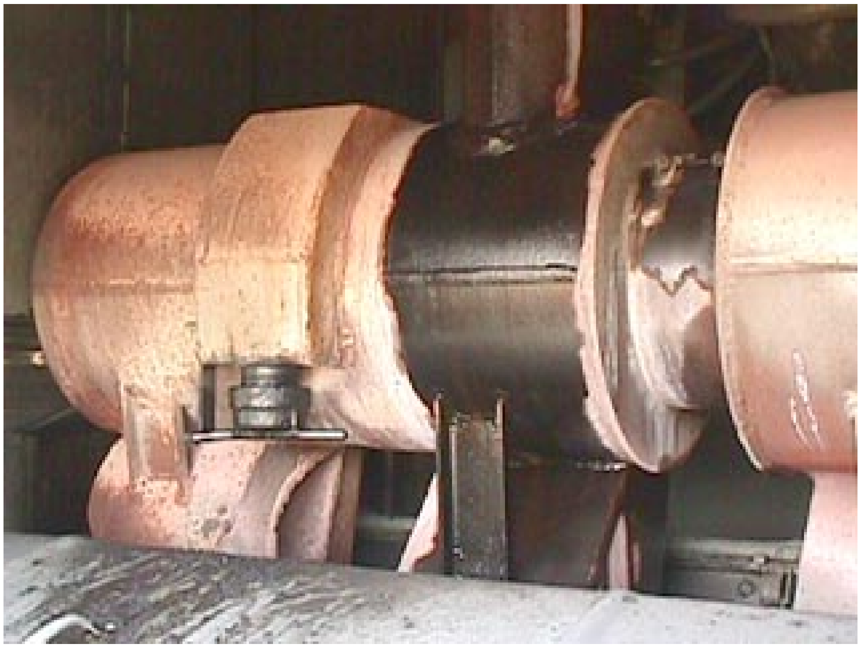
Photograph 5-6.
Exhaust Clean-Out Trap on Non-Turbo Engine

Photograph 5-7.
Clean-Out Trap (Note Carbon Lower-Left Corner)

Inspection Procedures

Inspections of the normally aspirated (non-turbocharged) locomotives will require that the unit be shut down while performing the inspection. Railroad personnel must perform this shutdown. If one or more of these units is to be inspected in a consist, only one unit needs to be shut down at a time. Inspectors should never start or shut down a locomotive.

Most normally aspirated locomotives are fitted with retention spark arresters. The side doors along the catwalk are opened to gain access to the caps on the carbon traps. Having been shut down, these carbon traps, the arrester and the exhaust manifold will be very hot - **WEAR GLOVES.**



Photograph 5-8.
Cup-Type Carbon Trap

Photograph 5-9.
Cup-Type Carbon Trap (Note Locking Mechanism on Right Side)

Retention trap caps should be removed and replaced by a company employee when possible. The trap caps will often require a tap from a hammer or wrench to start them to unscrew. Before removing the caps, provisions should be made for catching any carbon that may be inside the traps. This may be done with a coffee can or a piece of cardboard. After removing each cap, caked carbon should be freed from the inside. This may be done by tapping the trap with a hammer or by probing inside with a bent metal rod. After emptying the trap, the cap should be replaced snugly, but not excessively tight, and the vibration lock engaged.

5.2 Turbocharged Diesel Engines

On this type of engine supercharging is achieved by a blower that is driven by the exhaust gasses passing by impeller vanes mounted on a common shaft with the blower vanes. There are several makes and models of these but they all operate on the same principle. In most turbo-charged engines, crankcase fumes are not removed by direct suction as in the normally aspirated engines. Instead a venturi principle is used. This is commonly called an eductor. Consequently the carbon particles are like those in normally aspirated engines: hard, nonporous, and very hot. The difference is in their manner of disposal. The particles travel, with the gasses carrying them, through the impeller vanes of the turbocharger.

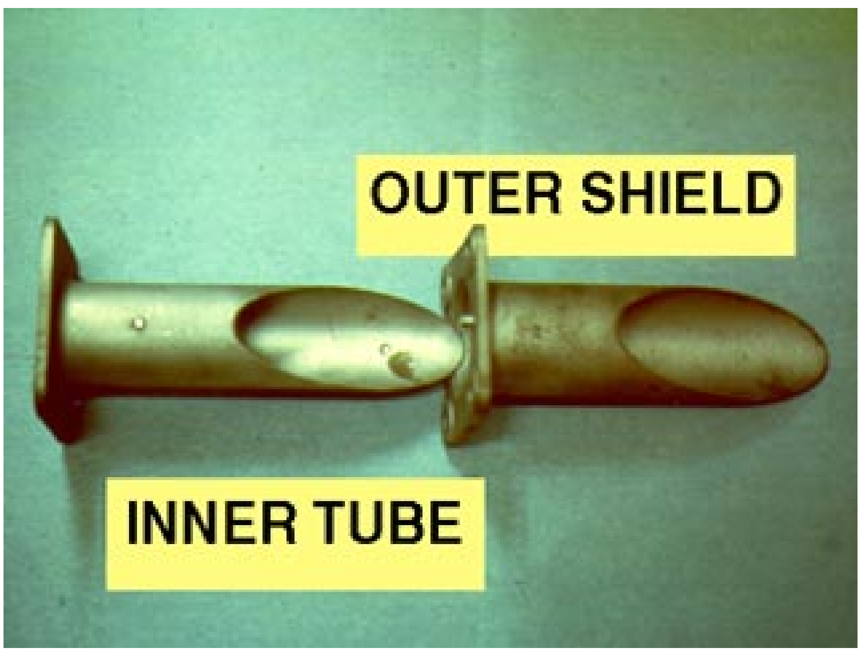
Photograph 5-10.
Inter Cooler

Photograph 5-11.
Turbocharger - GE

These high-carbon steel vanes are mounted close together and rotate at extremely high speed (approximately 20,000 RPM depending on make and model). Experience and limited testing suggest carbon particles are pulverized. This is not a fire risk assuming that all gasses go through the turbo and there are no malfunctions. The more common type of eductors found on larger road engines, mostly EMD (Electromotive Division of General Motors) and GE (General Electric), use the exhaust gasses after they have passed through the turbocharger to provide the venturi action on a tube connected to the crankcase through an oil separator.

Since oil separators are never 100% effective, a certain amount of crankcase oil is introduced into the exhaust gasses in the upper stack. The average temperature of these gasses under normal load conditions is 1100°F. Therefore, a certain amount of coking takes place in the stack around the rim of the eductor tube where more oxygen is available. With this configuration, most of the cylinder carbon is adequately disposed of by the turbocharger; however, soft and porous carbon is formed and introduced into the exhaust system. This carbon is different than cylinder carbon and in many ways more dangerous from a fire standpoint.

The pores are not void but full of oil. Although this carbon may not be as hot initially as cylinder carbon, it is hot enough to ignite the contained oil as soon as sufficient oxygen is present. Such particles have been observed coming out of the stack apparently cold and bursting into flame within a fraction of a second after alighting on flammable materials. This phenomenon has been verified by research at the U.S. Forest Service Fire Laboratory in Riverside, California. The above-described phenomenon can take place even when everything is operating normally. If any malfunction occurs, such as a clogged oil separator or a blown shaft oil seal on the impeller side of the turbocharger, excessive amounts of oil will be discharged into the hot exhaust gasses in the stack and the carbon build-up situation will be aggravated.



Photograph 5-12.
Eductor Tube

The two most common makes of turbocharged locomotives in use at this time (EMD and GE) have crankcase eductors that work on the same principle. However, they present quite a different appearance and different fire prevention problems. The standard EMD eductor tube is removable from the outside of the stack, and is thus easily cleaned of carbon or replaced. Its protective shroud is welded into the side of the stack. The shroud commonly becomes coked up the same as the tube itself, but it is much more difficult to clean. Several companies have developed their own special tools for this purpose. Industry and fire protection agencies have agreed on a 30-day or less maintenance cycle, and in some cases a 13 to 15-day cycle.

Photograph 5-13.
Dirty Eductor Tube

Photograph 5-14.
Looking Down Exhaust Stack with Eductor Tube

The GE eductor tube is considerably more difficult to clean. It is welded into the exhaust stack, thereby requiring cleaning from the top of the stack. The angle of the tube, the baffle in the tube and the presence of gratings over the top of the stack combine to make effective access significantly difficult. Again, various companies have developed special tools for this operation.

The mufflers also make it impossible to inspect or clean the eductor tube from the top. The tube must be removed for inspection and cleaning. Some models of EMD freight engines are equipped with exhaust silencers. They can be expected to present the same carbon build-up and inspection problems as do Amtrak locomotives.

Inspection Procedures

Inspections of turbo-charged locomotives do not require the unit to be shut down, **unless the unit is equipped with a muffler**. An exhaust inspection on most turbocharged locomotives requires looking down the stack from the top of the locomotive, because the condition of the eductor is of prime importance. This means climbing on top of the locomotive. Safety rules do not permit railroad personnel, except certain supervisors and mechanics to do this.

The inspector therefore should proceed with **CAUTION.** Most locomotives are fitted with handholds at each end **- USE THEM.** No other means of access to the top of the locomotive should be used. **LOCOMOTIVES ARE OFTEN QUITE DIRTY ON TOP AND EXTREME CARE MUST BE USED WHEN WALKING ON THEM. IF THE TOP OF THE LOCOMOTIVE IS WET, STAY OFF! SIXTEEN FEET TO THE RAIL IS A LONG WAY TO FALL.**

The fewest obstructions are encountered going up the cab end of most locomotives. However, climbing and descending is more difficult. If access is gained from the other end, walking from the end of the unit to the stack should be done over the dynamic brake and engine cooling fans to the stack. Each fan grating should be tested to determine if the grating is loose. Do not step on the bars supporting the cover. These cooling fans may start and stop at any time.

Photograph 5-15.
Top of Locomotive, Exhaust Stack

When on top of the locomotive, personnel must exercise extreme care so that nothing, e.g. pencils, eye glasses, mirrors, cameras, are dropped into the cooling fans or exhaust stack. All unneeded loose items should be left on the ground or secured inside buttoned pocket flaps. Any such foreign object can cause severe damage to the turbocharger. If your foot goes into a cooling fan, you may suffer severe damage.

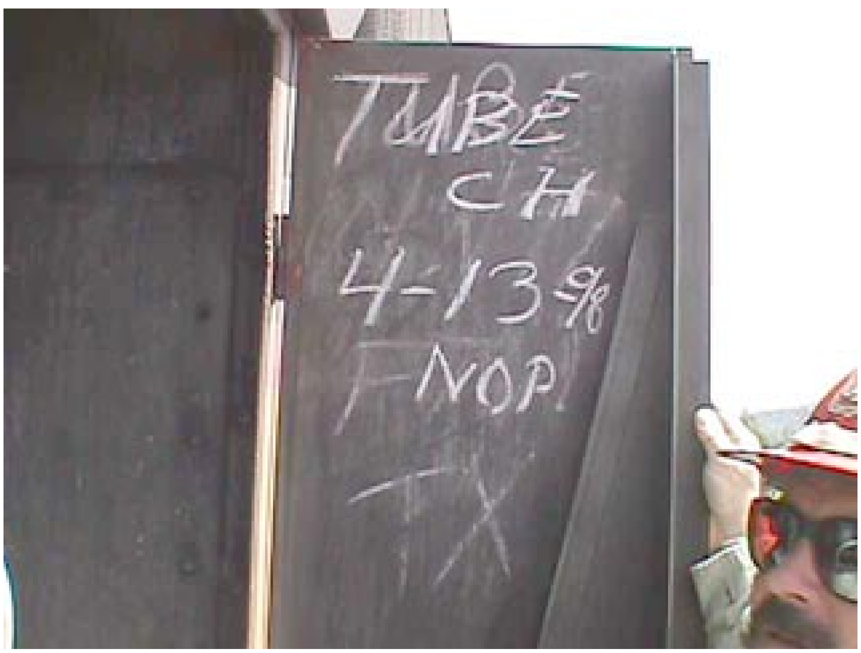
On turbo-charged locomotives that have a muffler, inspection of the eductor is not possible from the top of the unit. The eductor tube is hidden inside of the muffler and must be removed for inspection.

Newer and some retrofitted GE locomotives have been equipped with a coalescer which is intended to replace the eductor tube in the exhaust stack. A sticker that uses a circular symbol with a diagonal line through the eductor symbol may identify some of these locomotives. This sticker may be located on an outer compartment door on the locomotive.

Additionally, due to recent mechanical problems with the coalescer system, some of these coalescer-equipped locomotives have an eductor tube placed into the exhaust outlet. The non-eductor tube sticker may not have been removed from these units and will require a visual inspection of the exhaust outlet.

Recently, some railroad companies have established a practice of dating the eductor tube when it was last serviced by applying a date and location to the interior of the access door where the eductor tube is located. Look at the date, generally a 10 to15-day cleaning cycle is sufficient. Look at the gasket that seals the eductor to observe if the gasket looks new. This may be an indication that the eductor serviced occurred. If in doubt, look down the stack or have the eductor removed for inspection.

Photograph 5-16.
Looking Down Exhaust Stack with Eductor Tube



Photograph 5-17.
Date of Maintenance Marked on Inside of Engine Door

5.3 Amtrak

Amtrak passenger train locomotives are turbocharged diesel electric units. Thus, they present similar exhaust spark problems as discussed above. Because of noise pollution regulations, they are required to be fitted with silencers (mufflers). It has been found that these silencers tend to trap carbon particles until they build up an accumulation. The carbon may break loose and be expelled on the right of way. The silencers also make it impossible to inspect or clean the eductor from the top. The unit must be shut down and the tube removed for inspection and cleaning.

Photograph 5-18.
Disc Brakes

5.4 Steam Locomotives

Steam locomotives, fired by wood or coal were the original railroad fire setters. Fortunately, for fire protection agencies there are very few steam locomotives left. All these were either built for or converted to oil fuel. Their use is usually for tourist attractions and movie making, but they are still capable of starting fires and will be discussed briefly here.

Photograph 5-19.
Steam Locomotive

Carbon is formed in steam locomotives primarily in the boiler tubes and to a lesser extent any place where the exhaust gasses meet an obstruction or change direction. Carbon on the walls of the boiler tubes is not only a potential fire starter but also reduces the efficiency of the boiler by acting as a heat insulator.

It is, therefore important for the operating company to prevent any more than a slight build-up of carbon there. This is done by frequent sanding of the tubes. By this process, sand is introduced into the firebox and carried through the tubes by the strong draft. In the process it scours the sides of the tubes of carbon leaving bare metal. If this is done often enough, e.g. once a day, the carbon particles removed are too small to cause a right-of-way fire problem.

To make doubly sure that carbon sparks will not be emitted from the top of the stack, most railroad companies fit their steam locomotives with a double set of screens. One set is internal between the exhaust end of the tubes and the smokestack. The other set of screens is fitted to the top of the stack. These screens are subject to the same drawbacks as exhaust screens on diesel engines: clogging, backpressure, burning out, etc., however they are the only practical spark arresting system for steam locomotives.

Some people are concerned when they see flames apparently outside of the firebox. There is seldom anything to worry about. Ordinarily the in-draft is so strong that not only the flame but anything else that is loose is immediately drawn inside the firebox. About the only situation in which the firebox presents a wildfire problem is if the locomotive is parked where the right of way has not been cleaned of standing dry grass or litter.